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4. Title of the invention	GAS DISCHARGE LAMP DRIVE CIRCUITRY
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Gas Discharge Lamp Drive Circuitry

The present invention relates to an apparatus and method for driving a gas discharge lamp, and in particular for dimming fluorescent lamps or tubes.

Fluorescent lamps or tubes are widely used in the home, office and in industry to provide lighting. Such lamps generally consist of a tubular glass envelope, up to 2.44 m (8 feet) long, filled with an inert gas such as krypton or argon which when electrically excited in a gas discharge irradiates a fluorescent coating, such as a powder comprising a (Tb,Ce,Gd,Mg) borate, a (Eu,Ba,Mg) aluminate and a (Y,Eu) oxide, on the inside of the glass. An example of such a tube, 1.22 m (4 feet) long, is the model 'TL'D 36 Watt sold under the trade names "Super 80 (/840) New Generation" and "Standard (/33)" by Philips Electronic and Associated industries Limited.

It is desirable to be able to dim fluorescent tubes in order achieve increased energy efficiency when full lighting is not needed. It is known that such tubes up to 1.83 m (6 feet) long can be dimmed with appropriate control circuitry. For example, the above-mentioned 1.22 m fluorescent tube may be dimmably controlled with high frequency regulating ballast sold by Philips Lighting Limited as model number BPL136R.

With reference to Philips Lighting data sheet PL 3322, such known ballasts suffer from a number of limitations. First, it is only possible to achieve adequate control over the dimmable light output for fluorescent tubes up to 1.83 m (6 feet) in length. Secondly, it is only possible to dim down to about 10% of full light output before the tube flickers out. Thirdly, the lighting

efficiency of such dimming ballasts drops steadily as the light output falls, the efficiency being 56% at 25% light output and 27% at 10% output, as a result of increased thermal losses in the tube and ballast circuitry. Thus, the benefit of decreased electricity consumption is not fully realised at low power levels.

The reason for these limitations in performance appears to stem from the way conventional non-dimmable high frequency (hf) ballasts have been adapted for use as dimmable ballasts. A conventional hf ballast generates a pulsed voltage, typically at either 28 kHz or 35 kHz, modulated on and off at a low frequency (50 Hz or 100 Hz), with an on/off ratio of 50% so that there is no hf signal during each half-cycle. A conventional dimmable hf ballast reduces the on/off ratio so that the hf pulsed voltage becomes progressively less than 50% of the duty cycle. The hf pulses are therefore applied to the fluorescent tube for a lower average duty cycle and as fewer hf pulses are applied to the tube, the tube dims.

A number of limitations have been noted with such dimmable systems. First of all, because conventional fluorescent ballasts include a choke with a substantial inductance, proportionately greater amounts of energy are lost in ohmic heating of the choke as the tube is dimmed. Secondly, as the tube is dimmed, a point is reached where the tube fails to strike properly owing to the increasingly large proportion of time when the hf voltage is not applied to the tube. The tube therefore tends suddenly to flicker off before it has been fully dimmed, owing to the increasingly discontinuous nature of the pulse train applied to the tube. These problems become worse for increased length of fluorescent tube and consequently it is believed that there are no commercially

available dimmable ballasts for 2.44 m tubes, and the ballasts available for 1.83 m tubes do not work as well as those for 1.22 m tubes.

According to the invention, there is provided an electronic circuit for dimmably controlling a gas discharge lamp, comprising generation means for generating a high frequency pulse train that may be applied to the contacts of the lamp, and modulation means for varying the width of pulses in the pulse train so that the lamp may be dimmed as the width of the pulses is reduced.

Also according to the invention, there is provided an electronic circuit for driving a gas discharge lamp, comprising generation means for generating a high frequency pulse train that may be applied to the contacts of the lamp, the generation means comprising: means for producing a first and a second series of pulses; and means for combining the first and second series of pulses to produce the high frequency pulse train.

In a preferred embodiment of the invention, the lamp is a fluorescent lamp.

The term high frequency is intended to exclude frequencies above those used for mains supply, ie above 50 to 60 Hz. The value of the high frequency may depend on a number of factors, in particular the type of lamp and the physical size and power rating of the lamp.

The pulse train may comprise pulses of just one polarity, but preferably comprises pulses of both positive and negative polarity.

The modulation means may vary the width of each pulse in

the pulse train similarly, that is, so that the ratio of on/off time for each pulse is substantially the same.

It would, however, alternatively be possible to vary the width of each pulse in the pulse train dissimilarly, that is, so that the ratio of on/off time for at least some of the adjacent pulses in the pulse train are not substantially the same, so long as the gaps between pulses do not become so long that the pulse train becomes substantially discontinuous, so causing the tube to flicker off at lower average duty cycles.

When the circuit is for dimmably controlling a gas discharge lamp, the generation means may comprises means for producing a first and a second series of pulses, means for shifting the phase of the first series of pulses relative to the second series of pulses, and means for combining the first and second series of pulses to produce the high frequency pulse train.

Whether the circuit is for dimmably controlling or for steadily driving the lamp, the means for combining the first and second series of pulses preferably comprises a first transformer and a second transformer, the primaries of each transformer receiving respectively the first and second series of pulses, each of the secondaries having a tap which may be electrically connected to the contacts of the lamp and each having another tap electrically connected to a choke so that the choke combines the secondaries and choke in series between the contacts.

Then at least one of the transformers may have a secondary winding with a pair of taps that may be electrically connected to the heater elements of the lamp. One of the secondary taps for the heater element may then be

electrically connected to one of the secondary taps for the lamp contacts so that the heater elements can then receive high frequency pulses with a power level sufficient to heat the heater elements.

Preferably, this power level should be substantially constant and, in the case of the circuit for dimmably controlling the lamp, unaffected by the phase shifting of the first and second series of pulses with respect to one another.

Circuitry such as that described above is not bulky and may readily be incorporated in a light fitting having contacts for a gas discharge lamp. Alternatively, the circuit may be separate from the light fitting, although it would be necessary to provide appropriate transmission lines, eg coaxial cable, and shielding to prevent stray leakage of electromagnetic radiation.

The invention will now be further described by way of example to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a circuit for dimmably controlling a fluorescent lamp according to the invention, having a micro-controller which controls an inverter circuit connected to the lamp;

Figure 2 is a diagram of a pair of wave forms generated by the inverter circuit of Figure 1;

Figure 3 is a circuit diagram of the micro-controller of Figure 1;

Figure 4 is a circuit diagram of the inverter of Figure 1 connected to the lamp;

Figure 5 is a schematic diagram of the output from the inverter across the fluorescent lamp; and

Figures 6A to 6L are photographs of oscilloscope traces showing voltages representative of the current supplied by the inverter to the fluorescent lamp.

Referring first to Figures 1 and 2, a micro-controller 1 is connected to mains electrical power and a dimmer switch 2. The micro-controller has standard circuitry for mains rectification and stabilisation (not shown), and supplies an inverter circuit 3 with dc power at 320 V, in addition to low voltage dc supply V_{CC} at 5 V and V_{DD} at 12 V.

There is also a feedback line from the inverter 3 to the micro-controller 1, providing a voltage representative of the current drawn by the fluorescent lamp or tube 4, for compensating for line voltage variations and temperature variations of the tube.

The micro-controller digitally generates a pair of signals P_0 and P_1 which are fed into the inverter circuit 3 as inverter input signals. These input signals are each an essentially continuous train or series of pulses of 0-5 V dc square waves at about 39 kHz with a 50% duty cycle and, as will be explained in more detail further on, the signals P_0 and P_1 are in phase when the dimmer switch 2 is set for maximum and become progressively out of phase as the dimmer is turned down to off, at which point the signals are out of phase.

Output signals H_0, H_1 from the inverter 3 are connected to a fluorescent lamp 4, in this example a standard tube

2.44 m (8 feet) long with a rated power of 100 W. Each end of the tube has two contacts connected to the output signals H_0, H_1 for driving a heater filament in the lamp (not shown) and for supplying the voltage and current needed to strike and light the lamp.

Figure 3 is a circuit diagram of part of the micro-controller 1 comprising a programmable logic device (PLD) chip U1 manufactured by Advanced Micro Devices Inc. as part number MACH215. Chip U1 comprises a counter fed on line 13 a clock signal by a 20 MHz crystal X1. The dimmer switch 2 produces a standard 0-10 V dc output signal, which is converted to 0-5 V dc control input, before being digitized into eight bits D0-D7 by a microcontroller chip U2 manufactured by Arizona Microchip Inc as part number PIC16C73. The digitized control input is fed to lines 3-10 of chip U1. Each of these lines is connected to a 4.7 kohm pull-up resistor through resistor pack RP1 to the 5 V dc positive supply V_{cc} to ensure that a high signal has the correct voltage.

Chip U2 is powered on after a delay from a Reset in a conventional manner.

The 20 MHz signal from the crystal X1 is divided by 256 inside the chip UC1, and this yields a 78.12 kHz signal which is used by firmware in U1 to toggle an output line 41, labelled "PHASE 1A", of chip UC1 at 39.06 kHz. Line 39, labelled "PHASE 1B" is made the logical inverse of PHASE 1A so that the voltage difference between PHASE 1A and PHASE 1B is the square wave signal described in Figures 1 and 2 as the inverter input signal P_1. The absolute phase of this signal therefore does not vary.

Available inside chip UC1 is a count at 20 MHz from 0 to

255 over one-half cycle of the signal P_1. The 8 bits D0-D7 of the digitized 0-5 V control input signal representing the output of the dimmer switch 2 are then compared by firmware in chip UC1 with the 20 MHz count from 0 to 255. The chip UC1 output line 43, labelled "PHASE 0A", toggles from low to high, and from high to low, whenever the value of the digitized dimmer signal is equal to the value of the 20 MHz count. PHASE 0A, together with its logical inverse from line 40, labelled as "PHASE 0B", produce the square wave signal described in Figures 1 and 2 as the inverter input signal P_0. The absolute phase of the P_0 inverter input signal relative to the P_1 inverter input signal therefore may be varied from in phase (when the voltage from the dimmer switch is 10 V and the count value is 255) to out of phase (when the voltage from the dimmer switch is 0 V and the count value is 0).

Microcontroller U2 has outputs Run/Stop, Enable and Write Strobe passed respectively to control chip UC1 lines 11, 24, 25. The Write Strobe ensures that the chip UC1 latches in the 8 bit value D0-D7 representative of the dimmer switch setting at a defined point in the software cycle at which this value is compared with the 20 MHz count, so that a changing 8 bit value D0-D7 does not affect the operation of the firmware. The Run/Stop is used to switch off the inverter circuit 3 through two outputs from chip U1, lines 42 and 41, labelled respectively as "SHUTDOWN 0" and "SHUTDOWN 1", when the dimmer has been dimmed to zero.

The Enable line is not used in this embodiment of the invention, but could be used to implement pulse width modulation of the pulse train applied to the fluorescent tube 4. When Enable goes high, both P_0 and P_1 are made to

go in phase, whether or not the count is set to 255. It would therefore be possible to make the Enable line switch between high and low at a frequency below the high frequency pulse train at 39 kHz, but above mains frequency, for example high 10% of the time and low 90% of the time, so that the width of each pulse in the pulse train is varied dissimilarly, that is, so that the ratio of on/off time for at least some of the adjacent pulses in the pulse train are not substantially the same.

The inverter circuit 3 is shown in more detail in Figure 4, and comprises a pair of similar inverters receiving respectively the inverter input signals P_0 and P_1. Each signal is passed to a stepper motor driver chip with two drivers U3,U3A suitable for driving an inductive load, the chip being available from SGS Thompson Microelectronics as part number L293E. The chip U3,U3A is supplied with both V_{cc} at 5 V and V_{DD} at 12 V in order to convert input signals P_0 and P_1 to 12 V output signals OP1,OP2 and OP3,OP4, which are then coupled through similar transformers T2,T3 to a driver circuit which generates through one or the other of a similar pair of step-up output coupling transformers T0,T1, a square wave signal with a magnitude of 160 V matching the 0-5 V input signal P_0, P_1.

When the SHUTDOWN 0 and SHUTDOWN 1 lines are made high, chip U3,U3A allows the outputs OP1,OP2 and OP3,OP4 to float, thereby ceasing to drive the inverter circuit and so conserving power.

The 0 to $\pm$ 160 V output signal is generated in the following way. When an input signal goes high, a current is generated in a pair of separate input transformer T2,T3 secondary windings, each of these secondary windings then

produces a voltage across a pair of resistors R1,R2 and R3,R4 which is then used to switch on a pair of JFETS, each type IRF840, respectively Q1,Q2 and Q3,Q4, wired in series and spanning rectified power lines HT-, HT+ at 0-320 V dc. Because of the way the secondary taps of transformers T2,T3 are wired, when one JFET is on, the other is off, and vice versa, so producing an output voltage at ± 160 V across the primary winding of each inverter output transformer T0,T1 which follows the input voltage at 0-12 V across the primary winding of the corresponding inverter input transformer T2,T3.

The secondary windings of each of the output transformers T0 and T1 have taps TP10,TP20,TP30,TP40 and TP11,TP21, TP31,TP41 at the same number of turns, but in the opposite order so that the output voltages and currents are in the opposite sense. For each transformer, one pair of taps TP10,TP20 or TP11,TP21 supplying 4 V is connected across the heater elements in the fluorescent tube 4 to provide a sufficiently small heating current at 39 kHz which remains steady as the phases of the input and output signals are varied with respect to each other.

Another pair of taps TP30,TP40 and TP31,TP41 from each of the output transformers T0,T1 span most of the turns of the secondary windings. One tap TP30 or TP31 from each of the pairs of taps is connected, respectively to tap TP20 or TP21, and therefore also to one of the lamp heater contacts, with the other two taps TP40,TP41 being connected together through an inductor L3, so that most of the secondary turns of each of the output transformers T0,T1 together with the inductor L3 are in series.

The operation of the inverter circuit of Figure 4 with the fluorescent lamp 4 may be appreciated with reference also

to Figure 5 which shows schematically the voltage difference between the two taps TP30,TP31 (or, equivalently, the voltage difference between the two taps TP40,TP41). A dashed line at 0 V indicates the point at which there is no net voltage difference across these taps. When the signals P_0 and P_1 are out of phase, there is effectively no net voltage across the tube 4 and inductor L3. When the signals P_0 and P_1 are in phase, the voltages through the output transformers T0,T1 add, to produce the signal labelled in the drawing as "100% Power Output". The resultant voltages are also shown schematically for 25% and 75% output. The inverter circuit 3 therefore combines the pulse train signals P_0 and P_1 in such a way as to produce resultant voltages which have a varying pulse width for each positive and negative going pulse, the width varying from effectively 100% of a half cycle of the resultant pulse train down to 0% of a half cycle.

Figures 6A to 6L show photographs of oscilloscope traces of a voltage representative of the current through the inductor L3, taken at a time base of 5 μs per division. The twelve traces show the changes in current from nearly full power to nearly no power, and correspond with the data in Table 1 below:

Table 1:

Figure	Step N°	P (W) Meter	P (W) I•V	Light %	Effic P/L %	Temp (°C)
6A	219	120	123.2	100.0	100.0	31
6B	173	111	112.2	91.8	99.3	31
6C	150	101	101.2	83.7	99.4	29
6D	120	88	90.2	76.8	104.8	30
6E	106	81	81.4	71.4	105.8	29
6F	90	69	70.4	56.9	99.0	28
6G	77	60	61.6	45.2	90.5	27
6H	62	50	50.6	31.9	76.5	24
6I	50	40	39.6	21.5	64.6	22
6J	47	23	24.2	2.2	11.4	19
6K	28	20	19.8	0.5	3.3	17
6L	1	18	19.8	0.3	1.8	15

The "Step N°" value is the value of the digitized dimmer signal which shifts the phase of the signals P_0 and P_1 in and out of phase, with step number values of 255 and 0 being, respectively in phase and out of phase.

The "P Meter" values were measured with an electrical power meter on the mains supply to the apparatus; this measured value takes account of the power factor, that is any phase shift between current I and voltage V which would tend to reduce the consumed power. The "P I•V" values are calculated from measured values of mains supply voltage V and current I, with no correction for any phase differences between V and I. It will be noted that the close correspondence between the power levels as measured with the meter and those calculated from current I and voltage V shows that unlike conventional fluorescent drivers, the power factor is effectively unity, that is

there is effectively no phase shift between current and voltage. The circuit according to the present invention may therefore be useful even when the circuit is used just to drive a gas discharge lamp at a steady power, (ie with no phase shift of the first and second series of pulses) since there will be no cumulative shift in power factor as a large number of lamps and circuits are connected to the mains in close proximity with one another.

The mains voltage levels were steady at 220 V throughout the data run. The temperature values were measured with a probe on the glass envelope of the tube, which was a standard 2.44 m (8 feet) long fluorescent tube, manufactured by Osram and nominally rated 125 W.

The light levels were measured with a lux meter with the data normalised to 100% at the reading closest to nominal rated full power of the tube, ie 120 W, at which the "step number" was 219.

The column labelled "Effic" gives the relative efficiency of the lamp 4 and electronic circuitry 1,2,3, that is, a value representing Light/P Meter normalised to 100% at step number 219. It will be noted that the relative efficiency is still about 90% when the light has been dimmed to about 45% of nominal full output. Only when the light output has been dimmed to about 21% at a step value of 50, does the efficiency drop off sharply from about 65% when the step value is decreased to 47.

Further data taken using the same equipment and tube, but under ambient conditions warmer than those for the data of Table 1, are set out in Table 2 below for the full range of step values between 1 and 255.

Table 2:

Step N°	P (W) Meter	P (W) I•V	Light %	Effic P/L %	Temp (°C)
255	136	134.2	105.8	94.9	38
245	134	132.0	104.6	95.3	38
234	129	127.6	102.3	96.8	38
219	**122**	**118.8**	**100.0**	**100.0**	**38**
173	112	107.8	93.3	101.5	36
150	103	99.0	88.2	104.4	36
120	88	83.6	76.3	105.8	36
106	75	72.6	64.0	104.2	34
90	63	59.4	52.2	101.0	33
77	55	50.6	44.3	98.3	32
62	41	35.2	29.0	86.2	31
50	19	15.4	5.6	35.8	30
47	17	13.2	3.5	25.0	28
29	15	11.0	1.2	9.4	25
1	15	4.4	0.5	3.8	24

The data at step value 219 closest to the nominal 125 W rated power of the lamp is highlighted in bold on both tables for ease of comparison. The higher ambient temperatures lead to a higher actual light output, and therefore the step value below which the relative light output and relative efficiency begins to drop sharply, is here step number 62. The light output may, however, still be dimmed to about 29% of nominal full output at this point.

Although not implemented in the example described herein, the feedback line from the inverter 3 to the micro-controller 1, providing a voltage representative of the

current drawn by the fluorescent lamp or tube 4, may be used to compensate for temperature variations of the tube.

Referring again to Figures 6A to 6L, these show photographs of oscilloscope waveforms representative of the current through the fluorescent tube. In all cases the horizontal time base was set at 5 μs/division, making 50 μs across each photograph, with a vertical scale of 2 V/division. A voltage for the traces was generated by a current probe comprising a single turn of wire around the inductor L3, the current through the inductor L3 being essentially the same as the current through the fluorescent tube 4.

Since the inductor L3, together with the secondary windings of transformers T0,T1 between taps TP30,TP40 and TP31,TP41, is in series with the fluorescent tube 4, the impedance of the inductor L3 works as a current limiter to limit the current supplied from the inverters, and also to shape the rise and fall times of the current through the fluorescent tube. It has been found that the selected impedance of the inductor is important insofar as it shapes the rise and fall time of the current through the fluorescent tube 4. The inductor L3 uses a pair of square U-shaped ferrite cores, grade 3C85, manufactured by Philips Components, the arms of the U's aligned and facing each other with a 1 mm air gap therebetween. The overall dimensions of the ferrite assembly are 25 mm long (in the direction parallel to the arms) by 20 mm wide (in the direction parallel to the base of the U's) by 13 mm thick. Along one side of the assembly, and over one of the air gaps, are wrapped 110 turns of 0.4 mm copper wire.

The transformers T0,T1 have the same cores, but with no air gaps, and the same wire, with the primary having 93

turns, the secondary having a total of 169 turns with 4 turns being between taps TP10,TP20 or TP11,TP21 and 165 turns being between taps TP30,TP40 or TP31,TP41.

Correct design of inductor L3 helps the fluorescent tube to be dimmed to a lower level than would otherwise be possible. It is also important because if the lamp fails to strike, or flickers out at low power, the voltage across the inverters would increase and an auto-restrike would occur. Because of the high frequency operation, this would happen so quickly, that the eye would not be able to detect this restrike.

From Table 1, it can be seen that the apparatus according to the invention may be used to dim a standard 2.44 m (8 feet) long fluorescent tube to less than 1% of full light output. However, because of inevitable power losses in the electronic circuitry and essentially constant heating of the heater elements in the fluorescent tube, the effective range when power saving is the main concern is down to about 22% of full light output.

Although difficult to quantify, it has also been observed that the steadiness and the colour quality of the light output of fluorescent tubes driven by electronic circuits according to the invention, is superior to that achieved by conventional circuits of the type mentioned above. In particular, the colour quality appears to be more constant and whiter than with conventional apparatus as the power is dimmed towards nearly off.

Another advantage is that the power factor of the circuit as connected to the mains is close to unity, as can be seen from Table 1 by comparison of the columns for "Power" and "Power I•V". Conventional ballasts relying on

relatively large inductive chokes can induce a significant lag between voltage and current.

Although the invention has been described specifically with reference to a standard 2.44 m (8 feet) long cylindrical fluorescent tube, those skilled in the art will appreciate that the circuit described above may be adapted for other types of fluorescent tube, for example longer or shorter cylindrical tubes, and also compact fluorescent lamps such as those with shaped or curved tubes and those intended as replacements in incandescent light bulb fittings.

The electronic circuit according to the invention can also be used to drive and dimmably control other types of lamps such as metal halide and sodium vapour lamps. Such lamps are often used for outdoor lighting such as street lighting. The electronic circuit according to the invention may be then be used with such lamps to dim these when full light output is not needed, such as the small hours of the morning, this saving significant amounts of electrical power and reducing the problem of light pollution around built up areas.

For example, the circuitry described above has also been used to drive and dimmably control 70 W and 250 W high pressure sodium lamp of the type SON-T and also 250 W high pressure sodium lamps with a phosphorescent coating of the type SON-E. These lamps are noted for their high efficiency and used mainly for lighting of roads, and public buildings and spaces. Other lamps that have been successfully driven and dimmed are low pressure sodium lamps up to 180 W, type SOX manufactured by Osram, and high pressure mercury vapour lamps, up to 70 W.

It would also be possible to fit motion detectors, such as those using passive-infra-red sensors, to such dimmable lamps, to control automatically the degree of dimming, for example depending on whether anyone or any vehicle was moving near the lamp.

Gas discharge lamps driven and dimmably controlled by electronic circuits according to the invention may therefore be suitable for use in many applications in the home and industry, both indoor and outdoor.

Claims

1. An electronic circuit for dimmably controlling a gas discharge lamp, comprising generation means for generating a high frequency pulse train that may be applied to the contacts of the lamp, and modulation means for varying the width of pulses in the pulse train so that the lamp may be dimmed as the width of the pulses is reduced.

2. An electronic circuit as claimed in claim 1, in which the modulation means varies the width of each pulse in the pulse train similarly.

3. An electronic circuit as claimed in claim 1 or claim 2, in which the pulse train comprises pulses of both positive and negative polarity.

4. An electronic circuit as claimed in any preceding claim, in which the generation means comprises means for producing a first and a second series of pulses, means for shifting the phase of the first series of pulses relative to the second series of pulses, and means for combining the first and second series of pulses to produce the high frequency pulse train.

5. An electronic circuit as claimed in claim 4, in which the means for combining the first and second series of pulses comprises a first transformer and a second transformer, the primaries of each transformer receiving respectively the first and second series of pulses, each of the secondaries having a tap which may be electrically connected to the contacts of the lamp and each having another tap electrically connected to a choke so that the choke combines the secondaries and choke in series between the contacts.

6. An electronic circuit as claimed in claim 5, in which at least one of the transformers has a secondary with a pair of taps that may be electrically connected to heater elements of the lamp.

7. An electronic circuit as claimed in claim 6, in which the one of the secondary taps for the heater element is electrically connected to one of the secondary taps for the lamp contacts.

8. An electronic circuit as claimed in any preceding claim, comprising a motion detector to control automatically the degree of dimming.

9. A light fitting having contacts for a gas discharge lamp and an electronic circuit as claimed in any preceding claim.

10. An electronic circuit for driving a gas discharge lamp, comprising generation means for generating a high frequency pulse train that may be applied to the contacts of the lamp, the generation means comprising: means for producing a first and a second series of pulses; and means for combining the first and second series of pulses to produce the high frequency pulse train.

11. An electronic circuit as claimed in claim 10, in which the means for combining the first and second series of pulses comprises a first transformer and a second transformer, the primaries of each transformer receiving respectively the first and second series of pulses, each of the secondaries having a tap which may be electrically connected to the contacts of the lamp and each having another tap electrically connected to a choke so that the choke combines the secondaries and choke in series between

the contacts.

12. A light fitting having contacts for a gas discharge lamp and an electronic circuit as claimed in claim 10 or claim 11.

13. An electronic circuit for dimmably controlling a gas discharge lamp, substantially as herein described, with reference to and as shown in the accompanying drawings.

14. An electronic circuit for driving a gas discharge lamp, substantially as herein described, with reference to and as shown in the accompanying drawings.

Abstract

Gas Discharge Lamp Drive Circuitry

The present invention relates to an apparatus and method for driving a gas discharge lamp, and in particular for dimming fluorescent lamps or tubes. An electronic circuit for dimmably controlling a gas discharge lamp 4, comprises generation means 1 for generating a high frequency pulse train that may be applied to the contacts of the lamp 4, and modulation 3 means for varying the width of pulses in the pulse train so that the lamp may be dimmed as the width of the pulses is reduced. The generation means 1 comprises means for producing a first P_0 and a second P_1 series of pulses, means for shifting the phase of the first series of pulses relative to the second series of pulses, and means for combining the first and second series of pulses to produce the high frequency pulse train.

Figures 1 and 2

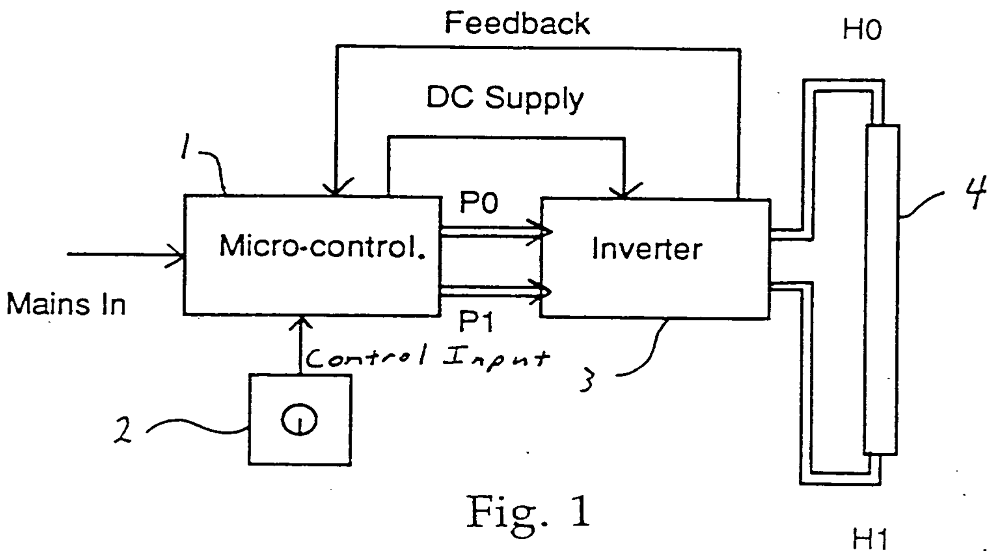
Feedback
H0
DC Supply
1
4
P0
Micro-control.
Inverter
Mains In
P1
Control Input
3
2
H1

Fig. 1

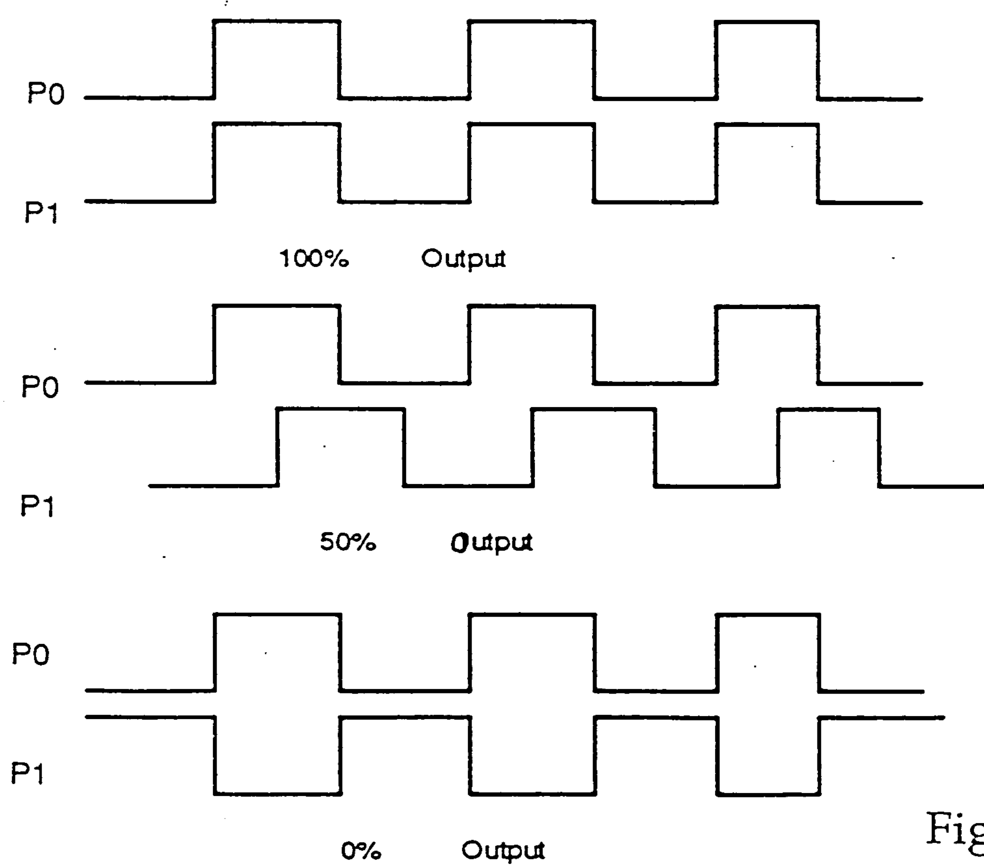
P0
P1
100% Output
P0
P1
50% Output
P0
P1
0% Output

Fig. 2

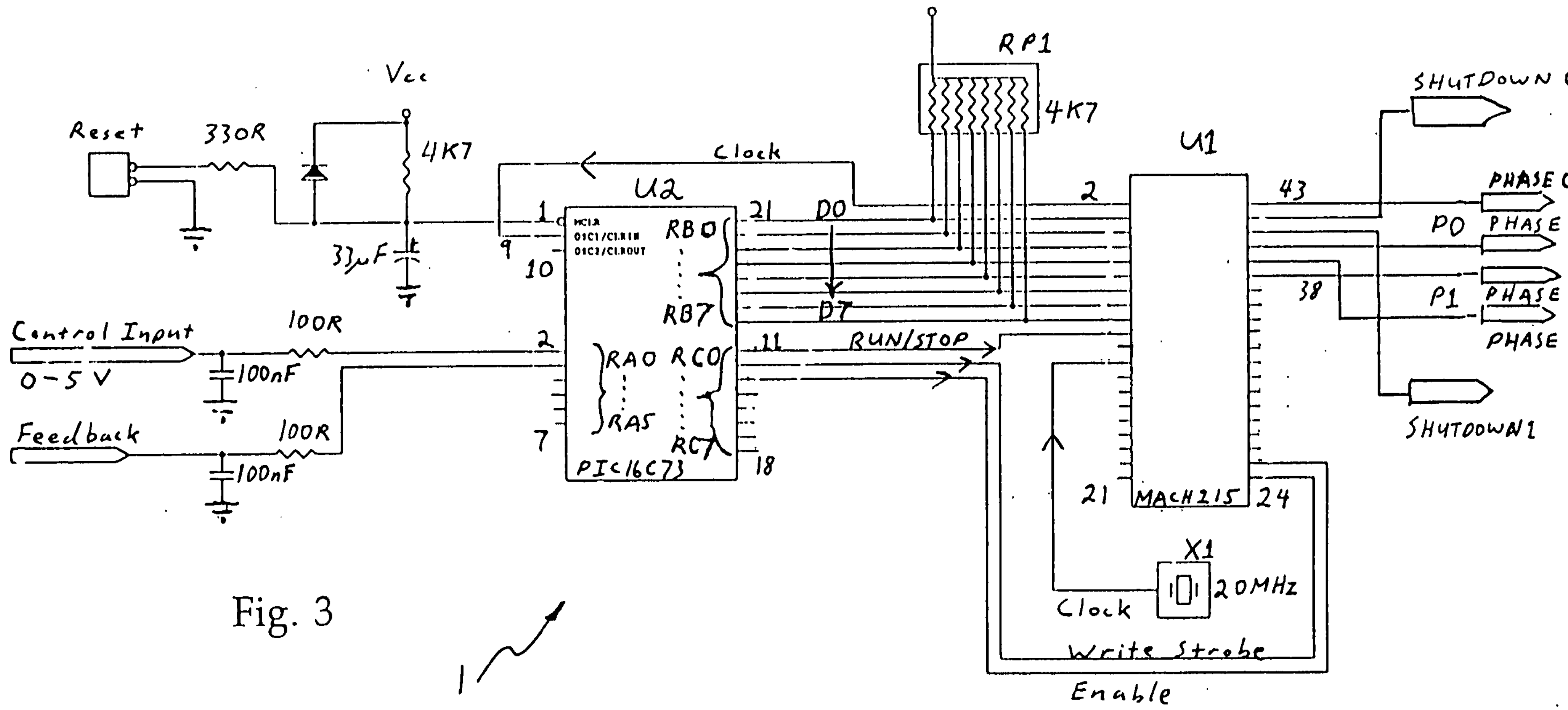
Reset
330R
Vcc
4K7
33μF
Control Input
0-5 V
100R
100nF
Feedback
100R
100nF
Clock
U2
1
9
10
2
7
21
11
18
RB0
RB7
RA0
RA5
RC0
RC7
PIC16C73
D0
D7
RUN/STOP
Vcc
RP1
4K7
U1
2
43
38
21
24
MACH215
X1
20MHz
Clock
Write Strobe
Enable
SHUTDOWN 0
PHASE 0A
P0
PHASE 0B
PHASE 1A
P1
PHASE 1B
SHUTDOWN1
1

Fig. 3

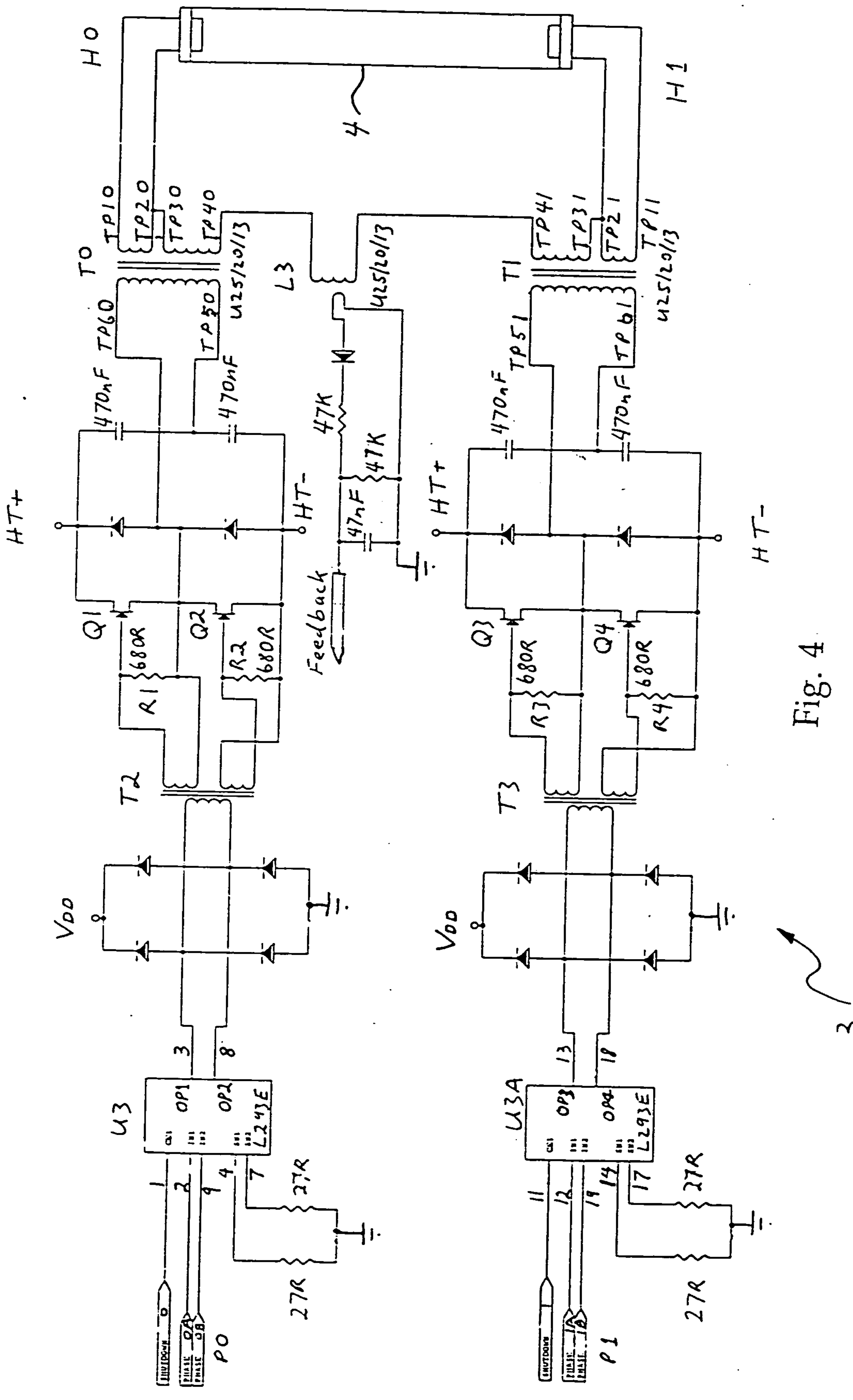
H0
H1
4
TP10
TP20
TP30
TP40
T0
u25/20/13
TP60
TP50
L3
T1
TP41
TP31
TP21
TP11
TP51
TP61
470nF
47K
47nF
HT+
HT-
Feedback
Q1
Q2
Q3
Q4
680R
R1
R2
R3
R4
T2
T3
VDD
U3
U3A
OP1
OP2
OP3
OP4
L293E
27R
P0
P1
3

Fig. 4

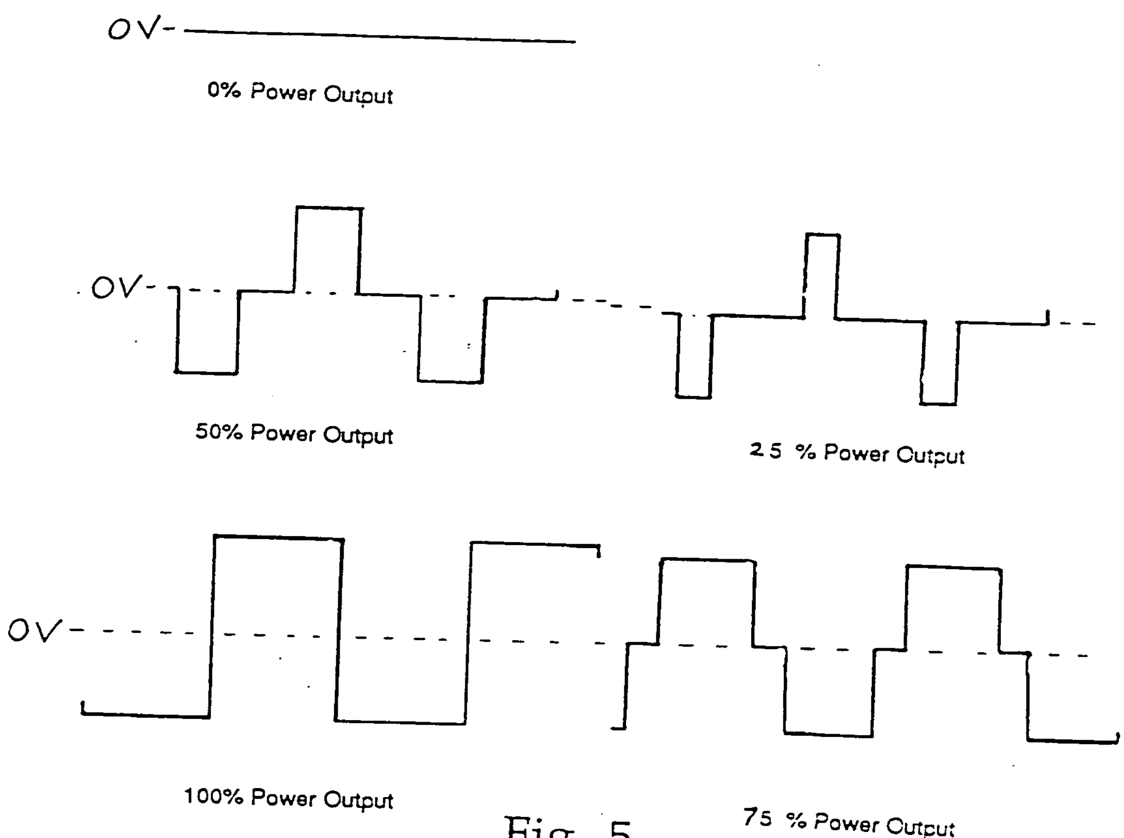
OV
0% Power Output
OV
50% Power Output
25 % Power Output
OV
100% Power Output
75 % Power Output

Fig. 5

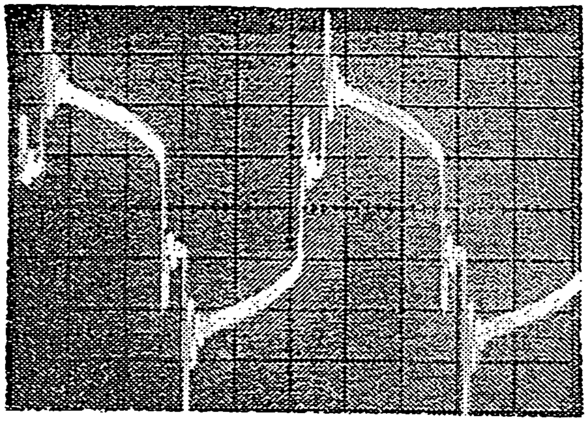

Fig. 6A Step No. 219

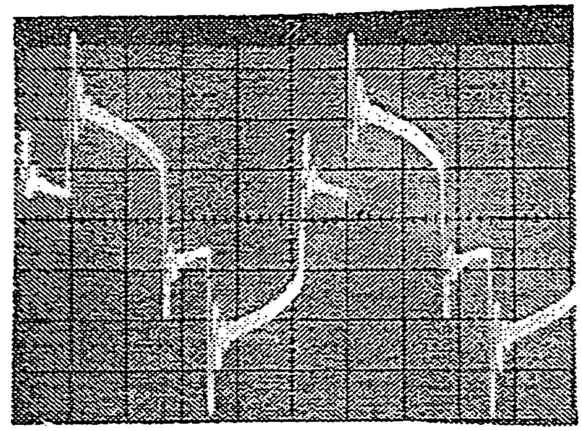

Fig. 6B Step No. 173

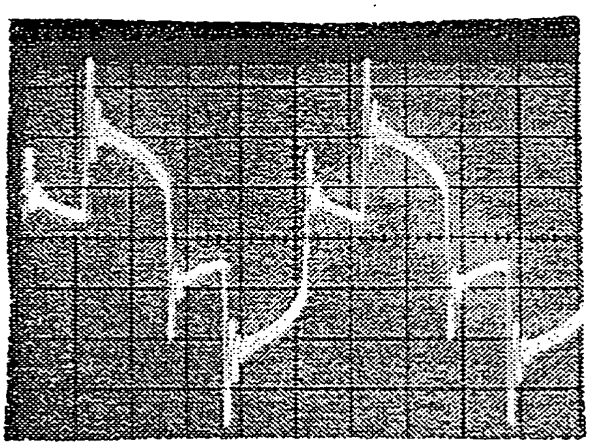

Fig. 6C Step No. 150

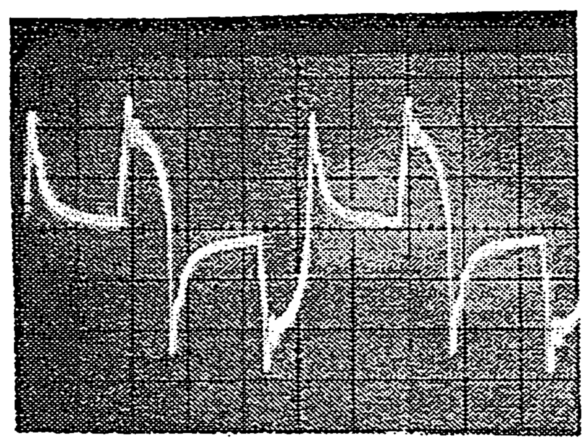

Fig. 6D Step No. 120

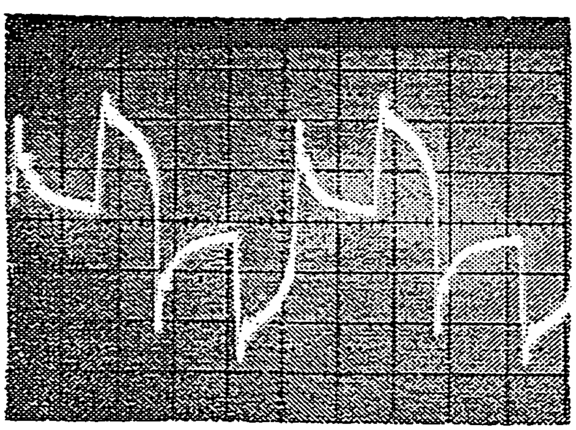

Fig. 6E Step No. 106

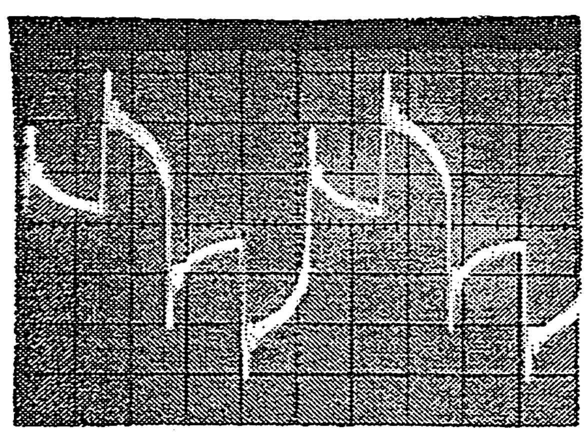

Fig. 6F Step No. 90

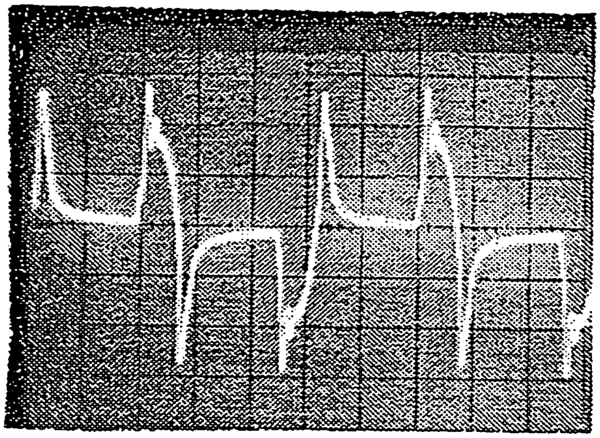

Fig. 6G Step No. 77

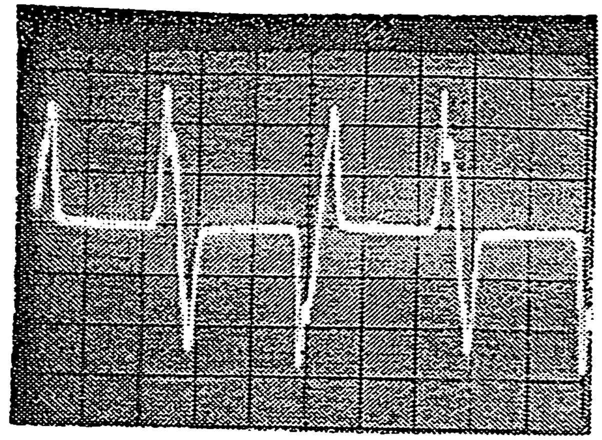

Fig. 6H Step No. 62

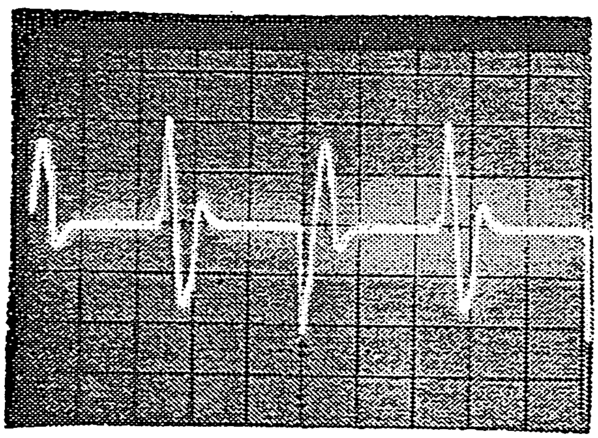

Fig. 6I Step No. 50

Fig. 6J Step No. 47

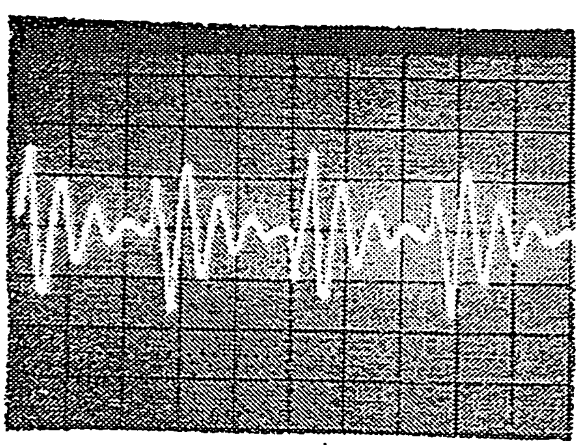

Fig. 6K Step No. 29

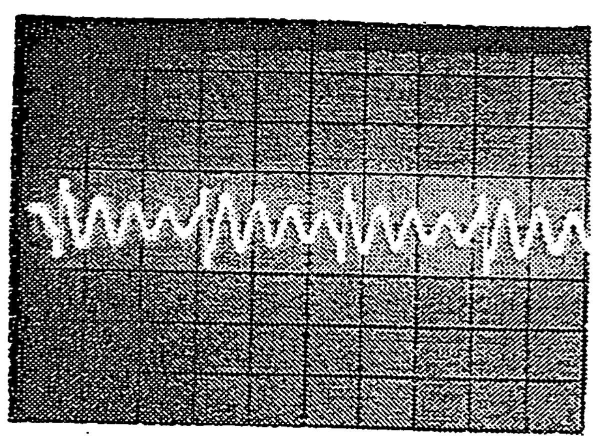

Fig. 6L Step No. 1

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